IN SITU MONITORING OF PHYSICAL PROPERTIES OF HIGH-LEVEL WASTE SLURRIES

TECHNOLOGY NEED

An estimated 381,000 cubic meters containing 1.1 billion curies (Ci) of radioactive waste are stored in high-level waste (HLW) tanks at the Hanford, Savannah River, Idaho National Engineering and Environmental Laboratory, and West Valley facilities. These nuclear wastes have created one of the most complex waste management and clean-up problems facing the United States. Release of radioactive materials to the environment from underground waste tanks requires immediate actions of clean-up and waste retrieval. Hydraulic mobilization with the use of mixer pumps will be the process used to retrieve waste slurries and salt cake from storage tanks. To ensure that transport lines in the hydraulic system will not plug, the physical properties of the slurries must be monitored. Characterization of a slurry flow needs reliable measurements of slurry density, mass flow, viscosity, and volume percent solids. The measurements are preferably made with in-line, non-intrusive sensors that can provide continuous real-time monitoring. The typical physical parameters of a HLW slurry transport line (e.g., the Hanford slurry transport line) are: (a) temperature range is 65 ^{0}F (18.3 ^{0}C) to 175 ^{0}F (79.4 ^{0}C); (b) particle size distribution is 0.5 - 4000 microns with 95% of the total less than 50 microns; (c) solid concentration is less than 30% by volume; (d) viscosity range is 1 - 100 cP; and (e) radiation level at the pipe wall is 61.8 R/hr.

TECHNOLOGY DESCRIPTION

The focus of this project in FY 1998 is to develop an ultrasonic instrument for measuring percent solids in waste slurry. Close monitoring of percent-solids concentration is important to tank-waste transporting process because it can provide a quantitative measure of solid wastes being transported and also an indication of flow conditions and, in particular, the extent of solid settling. Techniques applicable to the in-line measurement of solid concentrations are limited; the most common techniques are optical and ultrasonic techniques. Measurements of sound velocity and attenuation are the typical ultrasonic methods for solid-concentration monitoring. Between the two, the attenuation measurement generally provides a better correlation with solid concentrations. Ultrasonic attenuation techniques for measuring solid concentration were examined at ANL for coal slurry monitoring[1, 2] and studied theoretically recently[3]. Results indicate that the attenuation measurement can be used to monitor solid concentrations up to 40% by weight.

Acoustic attenuation in a solid/liquid slurry results from viscous, thermal, and scattering effects. Ideally, one would like to design a percent-solids monitor that operates in the frequency range where the scattering effect dominates. In practice, because of the wide ranges of particle concentrations and particle-size distributions, such an optimal frequency range cannot be realized. The alternative approach is to use a fixed frequency (1 MHz for the present case) that has a wavelength much larger than the average particle size and to measure the relative attenuation of slurry with respect to the suspending fluid. The relative attenuation, α_r, can be given as

$$\alpha_r = 20 \log \frac{P_s}{P_f} = \alpha_s - \alpha_f$$

where α represents attenuation; *P* stands for acoustic pressure; and subscripts *s* and *f* represent slurry and fluid, respectively. The relative attenuation defined in the equation is then directly related to absorption by and scattering from particles. However, to determine the relative attenuation, one needs to know the attenuation in the suspending fluid, which is typically obtained from off-line calibration measurements. Errors will be introduced if the actual fluid of the slurry differs from the calibration fluid. Therefore, the proposed technique requires additional measurements to provide real-time signals that relate to fluid properties. The instrument consists of a pair of transducers bonded onto stainless-steel

waveguides that will operate with both pitch-catch and pulse-echo modes. The pitch-catch mode measures both sound velocity and the attenuated signal amplitude while the pulse-echo mode gives an estimate of the acoustic impedance of the slurry. The acoustic impedance and sound velocity measurements will be used to characterize the slurry property, from which a correct calibration constant can be applied to the percent-solids measurement.

BENEFITS

Treatment of wastes at waste processing facilities requires the transfer of slurries between storage tanks. The slurries are typically a complex, multi-phase, and highly stratified mixture of saltcake, sludge, and supernatant. During transfer, transport lines may be plugged because of excessive solids in the slurry. The estimated cost to replace a plugged transport line at Hanford is $47 million. To avoid the transport lines being plugged, the slurry flow must be maintained in the turbulent flow region that requires a Reynolds number > 22,000, a specific gravity < 1.5, a viscosity < 30 cP, and a volume percent solids < 30. Therefore, *in situ* measurements of slurry density, viscosity, and volume percent solids will ensure the safe and continuous operation of waste transfer. Major benefits to the overall waste retrieval and cleanup are (1) maintaining a safe operation, (2) avoiding cost due to line plugging, and (3) providing waste accountability.

CAPABILITIES/LIMITATIONS

Because the technology is based on ultrasonic attenuation measurements, the instrument may, if gas bubbles are present, drastically overestimate the solids concentration. The instrument does not give an absolute measurement of solids concentration because the measured attenuation depends on many factors such as fluid composition, particle size, and temperature. However, after calibration the instrument can provide real-time monitoring of the percent-solids concentration. The instrument is easy to operate and operates at low cost.

COLLABORATION/TECHNOLOGY TRANSFER

The project will produce a practical, in-line, percent-solids monitor that has potential applications in many industrial processes--especially the processes involving the suspension of solids such as those in coal and paper/pulp slurries. The percent solids monitor will be transferred to the flow-instrument industry at its completion. The monitor can be further developed into a real-time flow imaging system that will increase its market value and industrial application.

ACCOMPLISHMENTS

In FY 1998, a new project was initiated that will develop an ultrasonic instrument for percent-solids measurements. The project started in February 1998. To date, the Technical Task Plan milestones were completed for FY 1998:

- **Laboratory Testing of a Sensor System for Percent-Solids Measurements.** This task will determine an optimal sensor configuration and measurement technique for monitoring percent-solids in solid/liquid slurries. Laboratory tests will be conducted at the ANL solid/liquid flow facility. Tests will use Kaolin/sugar water slurries of different percent-solids concentrations from 0 to 30%. Measurement sensitivity and resolution will be determined as a function of operating frequency, particle size, and solid concentration.
- **Design and Fabrication of a Prototype Instrument.** This task will design and fabricate a prototype instrument that will be installed at the ORNL hot-test facility. The required electronics and software control will also be developed. The effects on measurement accuracy will be examined for slurry-line process parameters including temperature, flow rate, fluid viscosity, and air bubbles.
- **Radioactive Hot Tests.** The percent-solids monitor will be tested at ORNL hot test facility. The instrument performance under the radioactive environment will be evaluated. A final report on the instrument will be issued.

References:

- [1]A. C. Raptis and S. H. Sheen, "Ultrasonic Properties of Coal Slurries and Flow Measurements by Cross Correlation," IEEE Trans. on Sonics and Ultrasonics, Vol. SU-28, No. 4, pp.248-256, 1981.
- [2]S. H. Sheen, A. C. Raptis, and W. P. Lawrence, "Advanced Research in instrumentation and Diagnostics Technology," Proc.12th Annual Gasification and Gas Stream Cleanup System Contractors Review Meeting, Vol. 1, pp. 180-188, 1992.
- [3]S. H. Sheen, H. T. Chien, and A. C. Raptis,"Ultrasonic Methods for Measuring Liquid Viscosity and Volume Percent of Solids," Argonne National Laboratory publication, ANL 97/4, April, 1997.

Laboratory tests have been conducted to obtain calibration data. Slurries of Kaolin particles of size <50 μm suspended in sugar water were used for the tests.

TECHNICAL TASK PLAN (TTP) INFORMATION

TTP No./Title: CH26C217 - Ultrasonic Sensors for *In Situ* Monitoring of Physical Properties

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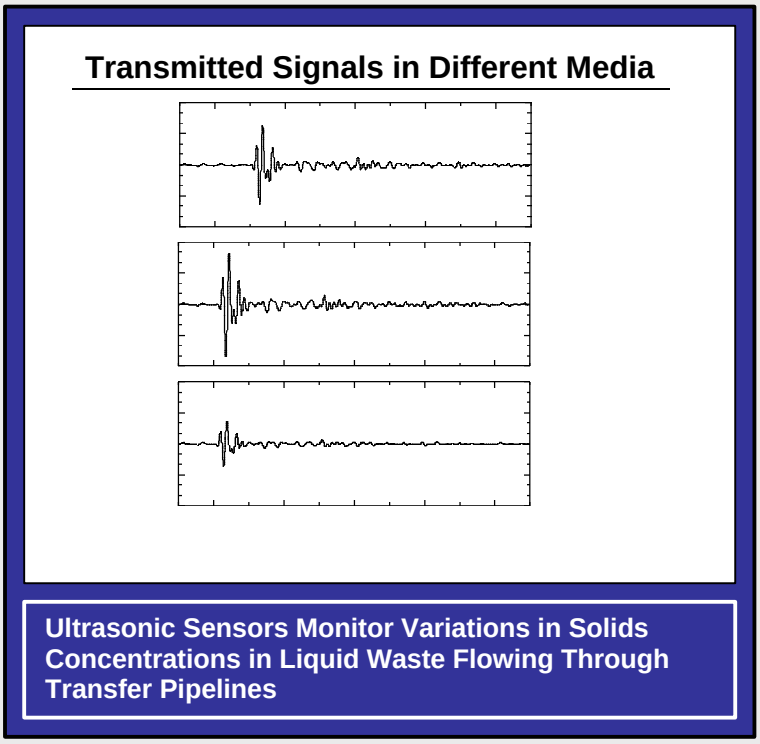

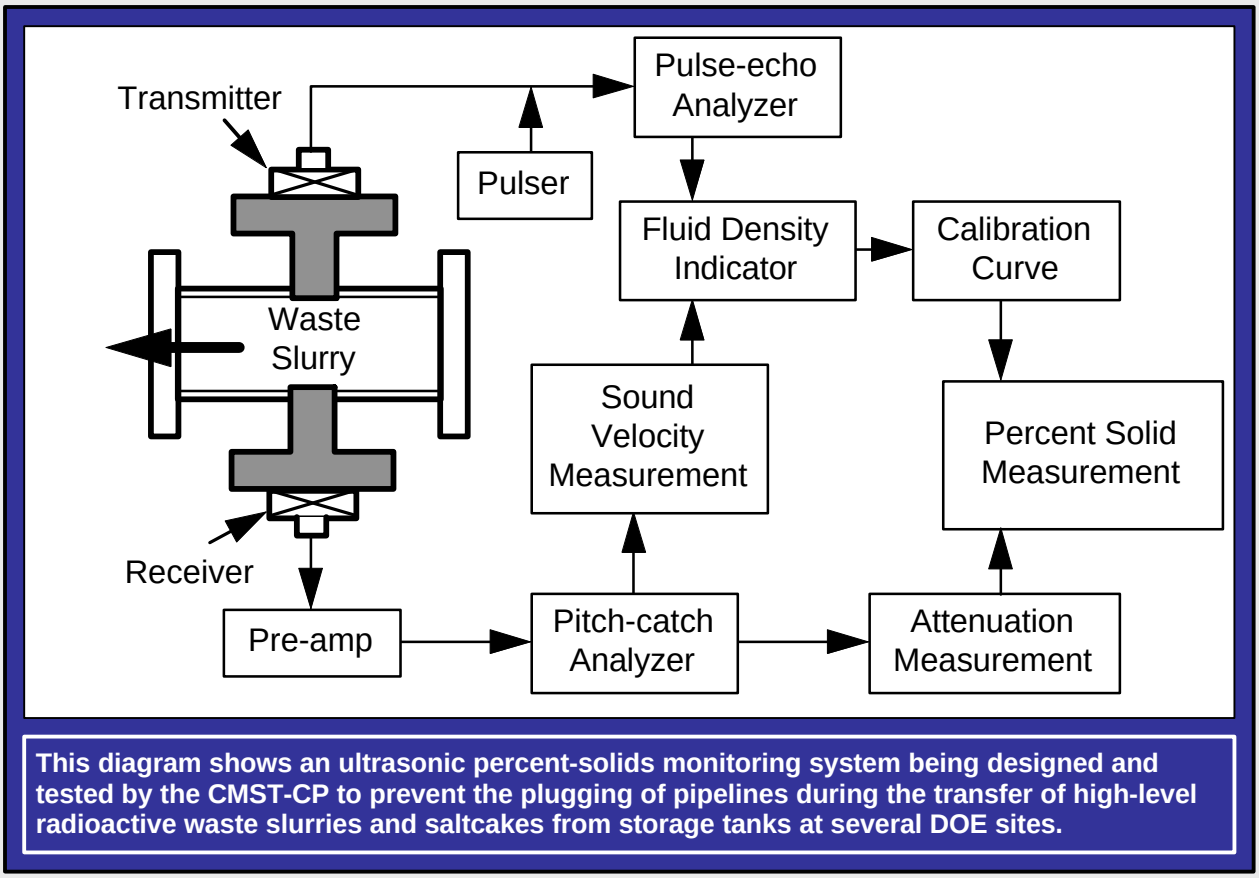

This diagram shows an ultrasonic percent-solids monitoring system being designed and tested by the CMST-CP to prevent the plugging of pipelines during the transfer of high-level radioactive waste slurries and saltcakes from storage tanks at several DOE sites.